Center for Clean Air Policy

Reducing CO_2 Emissions from California's Cement Sector

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Contact Information:

Center for Clean Air Policy
750 First Street, NE, Suite 940
Washington, DC 20002
202-408-9260
202-408-8896 (fax)
www.ccap.org

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Summary

At the request of the California Energy Commission, the Center for Clean Air Policy (CCAP) conducted an analysis of California's cement sector to determine the cost and magnitude of potential CO_2-emissions reductions from the sector. In its analysis, CCAP estimated future CO_2 emissions, the potential reductions in future CO_2 emissions, and the cost of these reductions for the period 2005 through 2025. This analysis was based on California-specific data and, where necessary, national data and assumptions.

At assumed annual sector growth rates of 2%, annual emissions from fuel and limestone consumption (direct CO_2) would rise from 10.4 million metric tons of CO_2 ($MMTCO_2$) in 2005 to 15.1 $MMTCO_2$ in 2025. Baseline emissions in 2010 and 2020 would be 11.3 and 13.6 $MMTCO_2$, respectively. Cumulative direct emissions over the period would amount to about 260 $MMTCO_2$. For the measures considered to reduce sector energy consumption and CO_2 emissions during 2005–2025, potential cumulative direct emissions reductions would amount to 47 $MMTCO_2$, or 2.2 $MMTCO_2$ annually on average. Of this cumulative (annual) amount, 38 (1.8), 36 (1.7), and 20 (1.0) $MMTCO_2$ would cost ≤ \$10/MT, ≤ \$5/MT, and ≤ \$0/MT, respectively. Even if all potential direct reductions were achieved, annual direct emissions would return to their initial value of 10.4 $MMTCO_2$ by 2017 and exceed it by 2.2 $MMTCO_2$ in 2025, reaching 12.6 $MMTCO_2$.

Among the measures considered to reduce energy consumption and CO_2 emissions, limestone Portland cement and blended cement accounted for 70% of the projected cumulative emissions reductions costing ≤ \$10/MT; including waste tires as fuel increased this fraction to 80%. While implementation of these measures could provide significant emissions reductions, market barriers currently impede their implementation. Under any future policy to reduce emissions from California's cement sector, these barriers must be addressed.

Based on the technical analysis, undertaking all measures considered that cost ≤ \$5/MT would result in 2010 and 2020 emissions of 9.6 and 11.8 $MMTCO_2$, respectively, corresponding to respective reductions of 1.7 and 1.9 $MMTCO_2$ from baseline emissions. Similarly, undertaking those costing ≤ \$10/MT would result in 2010 and 2020 emissions of 9.5 and 11.7 $MMTCO_2$, respectively, for respective relative reductions of 1.8 and 2.0 $MMTCO_2$.

Analytical Approach

The analysis of California's cement sector involved the following different technical components. California-specific data were used wherever possible; however, in the absence of such data (e.g., some energy-consumption statistics), national data and then assumptions were used.

1.) Future baselines for 2005–2025 were constructed for clinker and cement production and their capacities. Historical data were largely obtained from publicly available reports by the United States Geological Survey (USGS)[1]. While the historical data showed recent growth rates of ~2.5% for clinker and cement, discussions with industry representatives indicated that growth rates of up to 2% were more likely for this time period. Consequently, 2% growth rates were used to construct these future baselines. Lower/higher projected growth would lead to lower/higher future baseline CO_2 emissions. The choice of growth rates had some effect on projected future CO_2 emissions; however, it had a smaller effect on projected CO_2-emissions reductions relative to the baseline. For instance, 1% growth would reduce future baseline emissions by 15% relative to historical emissions and by 12% relative to 2% growth, but it would only reduce projected CO_2-emissions reductions by 5–10%. Figures 1 and 2 show emissions projections under 2% and 1% growth rate assumptions, respectively.

2.) Future baselines were developed for fuel and electricity consumption. These baselines were based mostly on historical national data; however, they also incorporated limited California-specific data for coal, petroleum coke, natural gas, and electricity. It was assumed in the baselines that energy efficiency would increase over time with newly installed clinker and cement capacities, consistent with historical trends as well as what technology improvements could yield.

3.) Future baselines for CO_2 emissions from fuel, electricity, and limestone consumption were derived from the above baselines and CO_2-emission factors. Direct factors for fuels were largely taken from publicly available documents by the United States Environmental Protection Agency (see especially, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2002*). The indirect factor for electricity was assumed to be the amount of CO_2 emitted per unit of average grid electricity consumed in the WECC. This factor was derived from projected data in the Department of Energy's *Annual Energy Outlook 2005* (*AEO 2005*). A direct CO_2-emission factor for limestone was developed from national data on raw-material inputs to clinker production.

4.) Information was collected on the benefits, costs, and technical potentials of energy-efficiency (EE) and other measures to reduce energy consumption and CO_2 emissions in clinker and cement production. Data on these measures were largely taken from various publicly available reports by Lawrence Berkeley National Laboratory (LBNL)[2]. Because these reports did not contain California-specific data, some of their data were altered when appropriate to better comport with conditions in California's cement sector (e.g., its higher-than-average energy efficiency). In the case of California-specific technical potentials, data from a recent draft report by LBNL for the Energy Commission, as well as from industry representatives, were used in the analysis[3]. Because measure benefits were given in energy per unit of clinker or cement, they were translated into monetary benefits via projected future energy prices from *AEO 2005*. Also, to the extent that a measure displaced some amount of clinker production (e.g., blended cement), the measure received fuel, electricity, limestone, and cost credits for the clinker displacement. Finally, for some of the largest capital-intensive measures, additional down time beyond scheduled maintenance was assumed to occur in 2005; this resulted in additional costs from lost production, as well as reduced energy consumption and CO_2 emissions, in 2005. All prices and costs were denominated in constant 2003 dollars, whether as originally cited in source documents (e.g., *AEO 2005*) or subsequently adjusted by CCAP.

5.) Potential cumulative reductions in energy consumption and CO_2 emissions from measure implementation and their cumulative net costs were computed from the above baselines and measures data. To set a likely upper limit on potential emissions reductions, all measures, except maintenance items and limestone Portland cement, were implemented at their technical potentials in 2005 for reductions during 2006–2025; the exceptions were implemented during 2006–2025 for same-year reductions. A measure's cumulative net cost was calculated by discounting its 2005–2025 stream of projected annual total costs back to 2005 at an annual rate of 7%. To assess the effect of discount rate, rates of 4% and 20% were also used. Cumulative net costs could be positive (cost), zero, or negative (savings), and could vary with discount rate.

6.) Abatement-cost curves for cumulative direct CO_2 emissions were constructed from the above potential cumulative CO_2-emissions reductions and net costs of the measures considered. These curves indicate the quantity of cumulative CO_2 emissions avoided by each measure relative to the baseline at its average unit (abatement) cost. A measure's average unit cost was calculated by dividing its cumulative net cost by its cumulative CO_2-emissions reduction. Relative to the 7% discount rate, the 4% rate tended to increase the magnitude of average unit cost whereas the 20% rate tended to decrease it.

7.) Projections of future annual direct CO_2 emissions were constructed from the above baselines and abatement-cost curves. These projections illustrate the potential trajectories of future emissions under different levels of measure implementation as determined by average unit cost.

Analytical Results and Discussion

Based on CCAP's analysis[4], baseline annual direct CO_2 emissions would increase from 10.4 $MMTCO_2$ in 2005 to 15.1 $MMTCO_2$ in 2025 at assumed sector growth of 2% annually (Figure 1). Baseline emissions in 2010 and 2020 would be 11.3 and 13.6 $MMTCO_2$, respectively. Over the period, cumulative baseline direct emissions would total 263 $MMTCO_2$. Sector measures for reducing energy consumption and CO_2 emissions during the period could achieve cumulative direct reductions of up to 47 $MMTCO_2$ relative to the baseline (Figure 3). The corresponding average annual reduction during the period would be up to 2.2 $MMTCO_2$. Of this cumulative (annual) amount, 38 (1.8), 36 (1.7), and 20 (1.0) $MMTCO_2$ would cost ≤ \$10/MT, ≤ \$5/MT, and ≤ \$0/MT, respectively (7%

discount rate; Figure 3, heavy solid line). Changing the annual discount rate from 7% had some effect on the cumulative (annual) amount at ≤ \$10/MT, ≤ \$5/MT, and ≤ \$0/MT (Figure 3): at 4%, 38 (1.8), 38 (1.8), and 24 (1.1) $MMTCO_2$, respectively; and at 20%, 36 (1.7), 36 (1.7), and 20 (1.0) $MMTCO_2$, respectively. Even if all potential direct reductions were achieved (Figure 1, heavy dashed line), annual direct emissions would return to their initial value of 10.4 $MMTCO_2$ by 2017 and exceed it by 2.2 $MMTCO_2$ in 2025, reaching 12.6 $MMTCO_2$.

With regard to future sector-wide emissions, undertaking all measures considered that cost ≤ \$5/MT would result in 2010 and 2020 emissions of 9.6 and 11.8 $MMTCO_2$, respectively, corresponding to respective reductions of 1.7 and 1.9 $MMTCO_2$ from baseline emissions. Similarly, undertaking those costing ≤ \$10/MT would result in 2010 and 2020 emissions of 9.5 and 11.7 $MMTCO_2$, respectively, for respective relative reductions of 1.8 and 2.0 $MMTCO_2$.

Among the measures considered to achieve cumulative reductions, limestone Portland cement and blended cement accounted for 70% of the cumulative 38 $MMTCO_2$ reduced at ≤ \$10/MT; inclusion of waste tires as fuel increased this proportion to 80%:

- Limestone Portland Cement, 12.6 $MMTCO_2$ at (\$21)/MT (net savings);
- Waste Tires as Fuel[5], 3.6 $MMTCO_2$ at (\$14)/MT (net savings); and
- Blended Cement (fly ash), 14.0 $MMTCO_2$ at \$2.40/MT.

Despite the attractiveness of these three measures for reducing CO_2 emissions, each has implementation issues. For limestone Portland cement, the lack of market acceptance impedes its use even though it is used in other countries and the American Society for Testing and Materials (ASTM) International has issued a standard for it. In addition, Cal Trans has raised questions about the structural integrity of limestone blends. For waste tires as fuel, significant public resistance prevents further penetration of this option in the cement sector. While three cement plants recently burned tires, three more did not even though licensed to do so[6]. For blended cement, the required fly ash[7] is not available in California and must be obtained from (at best) neighboring states. Notwithstanding fly-ash availability, existing cement standards largely prevent the use of blended cement even though its use is widespread in other countries. To achieve the potential emissions reductions from these measures, their implementation barriers must be addressed by state policies.

Policy Discussion

Beyond addressing the implementation barriers described in the last section, California could establish incentives or policies to encourage or require emissions reductions from the cement sector. State policies to reduce CO_2 emissions from the cement sector can take several forms in principal: technology mandates, direct implementation subsidies from public funds, indirect implementation subsidies through the tax code, negotiated agreements, emissions-intensity benchmarking, and an absolute cap on emissions, with or without trading. In practice, some forms will be more efficacious than others (Table 1).

Table 1
Overview of Policy Options

Form	Advantages	Disadvantages
Technology Mandates	Total sector participation	Less potential for innovation; Potentially high compliance costs
Direct Cost-Sharing with Public Funds	Financial incentives; Flexibility	Public and other sector disapproval; Susceptible to budget process
Indirect Cost-Sharing via State Tax Code	Financial incentives; Flexibility	Public and other sector disapproval; Improper/Ineffective distribution of financial incentives
Negotiated Agreements	Flexibility	Potential for uneven agreements across sector
Emissions-Intensity Benchmarking	Total sector participation	Absolute emission increases possible due to output growth exceeding reduction in CO_2 per unit output
Cap-&-Trade System	Total sector participation; Emissions target; Sector-wide flexibility	Cap perceived as restriction on sector growth
Cap Only System	Total sector participation; Emissions target	Less flexibility, higher compliance costs relative to Cap-&-Trade; Cap perceived as restriction on sector growth; Greater need to get cap level(s) right

Technology mandates have the virtue of sector-wide participation; however, because mandates do not allow much flexibility, they may be less effective in sectors with significant technological variations among sector entities, such as in cement production. Because technology mandates cannot account for future technological advances, they may lead to overinvestment in the “wrong” technologies and impede innovation. The low level of flexibility combined with a lack of emissions trading can be expected to result in relatively high compliance costs.

A cost-sharing program to directly subsidize measure implementation with public funds has the advantages of giving economic incentives and implementation flexibility to the cement sector, but it may not be viewed favorably by the public, or other industrial sectors. Because such a program is likely susceptible to the vagaries of future legislative appropriations and also voluntary, it may fail to lead to the desired level of emissions reductions.

Similarly, a cost-recovery program to indirectly subsidize implementation via the state tax code beyond current depreciation allowances provides economic incentives and implementation flexibility to the cement industry, but it also may be viewed unfavorably by the public, or other sectors. In addition, because cost recovery via the tax code may not effectively and appropriately distribute financial incentives for implementation within the sector, it also may fail to lead to the desired level of emissions reductions.

Negotiated agreements, whether voluntary or mandatory, have the virtue of providing flexibility to industry; however, because of their negotiated nature, they may only capture the emissions reductions that also yield net savings to industry.

A cap-&-trade system for CO_2 emissions has the advantages of sector-wide participation, a sector-wide emissions target, and maximal technological and financial flexibility for the sector to meet its target. The cement industry may be well suited to participation in a trading system given the relatively small number of plants. However, the use of a cap may be perceived by industry to restrict sector growth, though a facility has the option of purchasing the additional allowances that may be needed to allow for increased production.

A cap system without emissions trading also has the advantages of sector-wide participation and emissions target. While sector entities have the flexibility to determine how to make reductions, they must make any necessary reductions on-site to meet the cap. The inability to trade emissions can be expected to reduce flexibility and to increase compliance costs relative to a cap-&-trade system. A cap without the option for emissions trading may also restrict sector growth.

Emissions-intensity benchmarking has the advantage of lowering CO_2 emissions per unit of output (i.e., clinker, cement, or both). While benchmarking does allow for sector growth, it cannot guarantee that absolute sector-wide emissions will decrease, as sector growth may exceed the reduction in emissions intensity over time.

Any mandatory control program for this sector, whether benchmarking, technology-based approaches, or cap-and-trade, will open the possibility for leakage of emissions through increases in cement imports. As costs increase for California cement manufacturers, out-of-state and out-of-country imports will become more economically attractive. And the degree to which emissions per ton of output for these plants are higher than for in-state plants, the net result could be an emissions increase. On the other hand, to the degree that these plants have lower emissions, there could be a net benefit. The likely impacts of leakage for this sector should be studied further. In the event that a remedy is needed, there is the possibility of creating border adjustments that would level the environmental compliance requirements applicable to in-state and out-of-state producers.

Moreover, to enable industry to achieve the greatest emissions reductions from the various measures considered under any design of emissions-reduction policy, state policies will need to remove or lower the barriers that impede the use of limestone Portland cement, blended cement, and perhaps waste tires as fuel. The following policy changes are needed. For limestone Portland cement and blended cement, the state should codify their use in public-works projects and encourage it in the private sector. For waste tires as fuel, while the state already licenses cement plants, among others, to use them, the state should take a more-active role in explaining the benefits of their use to the public. Such benefits include reduced coal consumption, CO_2 emissions, mosquito vectors, and air pollution from open tire burning. At the same time, the state should demonstrate to the public that kiln combustion of waste tires results in the cited environmental benefits.

Endnotes

[1] USGS reports are available at http://minerals.usgs.gov/minerals/pubs/commodity/cement/.
[2] LBNL reports are available at http://ies.lbl.gov/iespubs/ieuapubs.html. See particularly reports LBNL-44182 and LBNL-54036.
[3] The draft report dated February 2005 was provided to CCAP via personal communication with Energy Commission staff.
[4] Sums and differences may not compute because of rounding.
[5] This analysis assumed that waste tires would otherwise emit CO_2 without providing process energy. In other words, the analysis assumes that the tires would normally be combusted. This assumption was used by LBNL in its recent draft report for the Energy Commission. If this assumption is not true, for example, if the waste tires are normally deposited in a landfill, then the use of waste tires will not provide these reductions and may even increase CO_2 emissions, depending on their alternative use. In the latter case, this measure would not be recommended; however, because the measure may be profitable to industry, industry could twin this measure with a more-expensive measure, achieving combined emissions reductions at a combined lower cost.
[6] See *2003 Report to the California Legislature on Emissions from Tire Burning in the State* by the California Air Resources Board at http://www.arb.ca.gov/mandrpts/mandrpts.htm.
[7] While blended cement can also be made with granulated blast furnace slag (GBFS), GBFS sources are much more remote to California than fly-ash sources; therefore, the average unit cost of blended cement with GBFS is much higher, estimated at $70/MT.

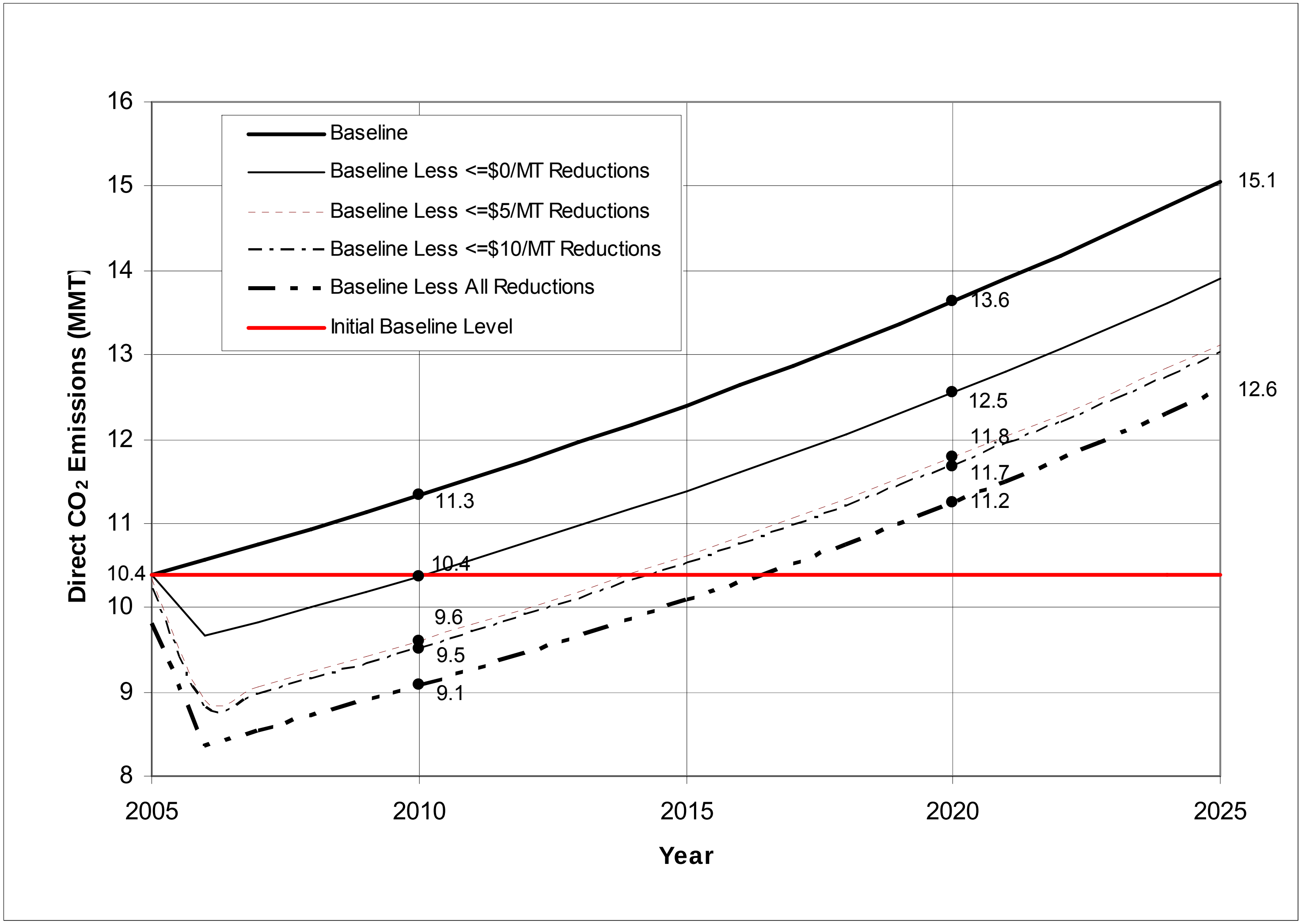

Figure 1: Projected Annual Direct CO_2 Emissions from California's Cement Sector from 2005–2025 at annual sector growth of 2% and discount rate of 7%.

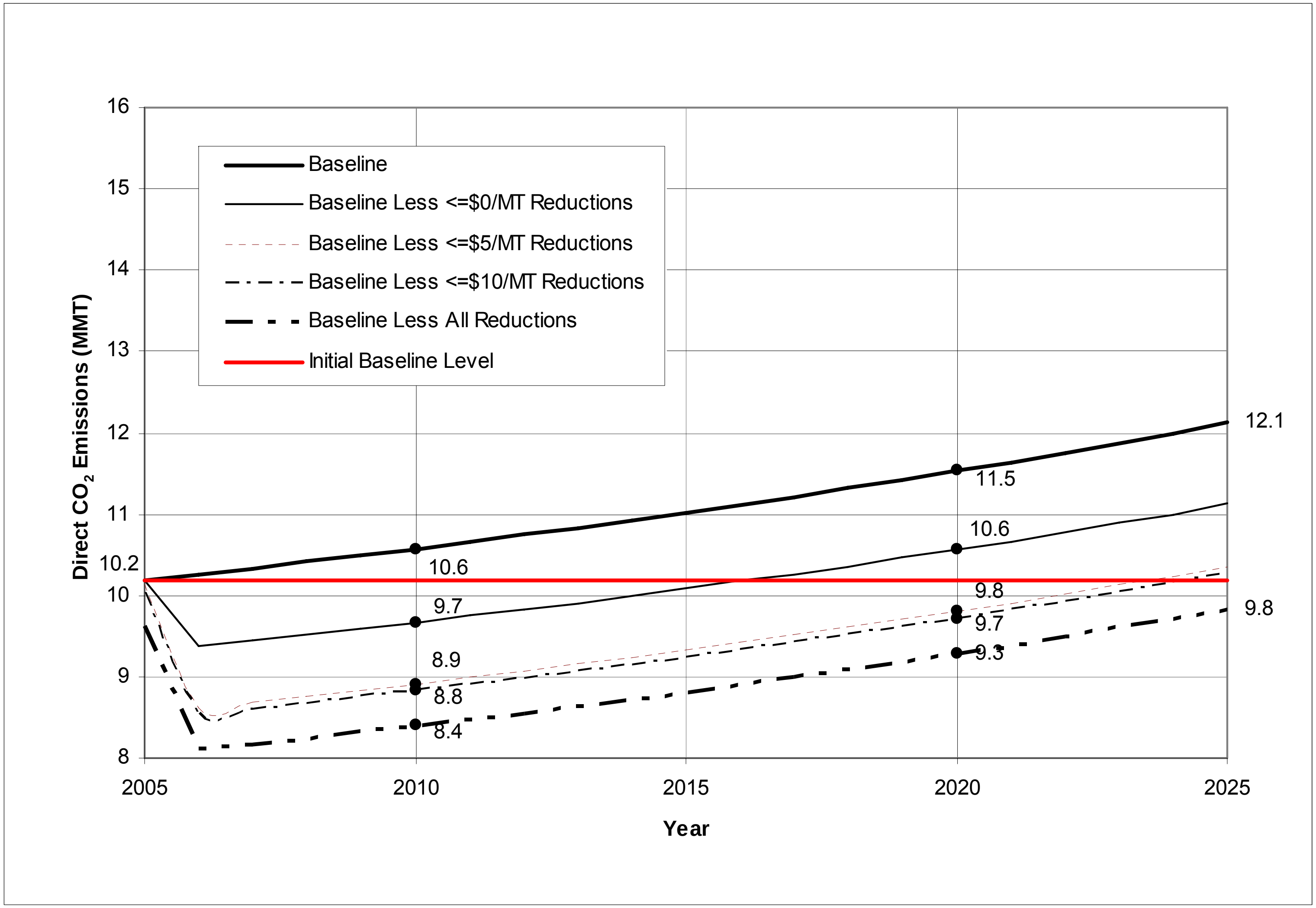

Figure 2: Projected Annual Direct CO_2 Emissions from California's Cement Sector from 2005–2025 at annual sector growth of 1% and discount rate of 7%.

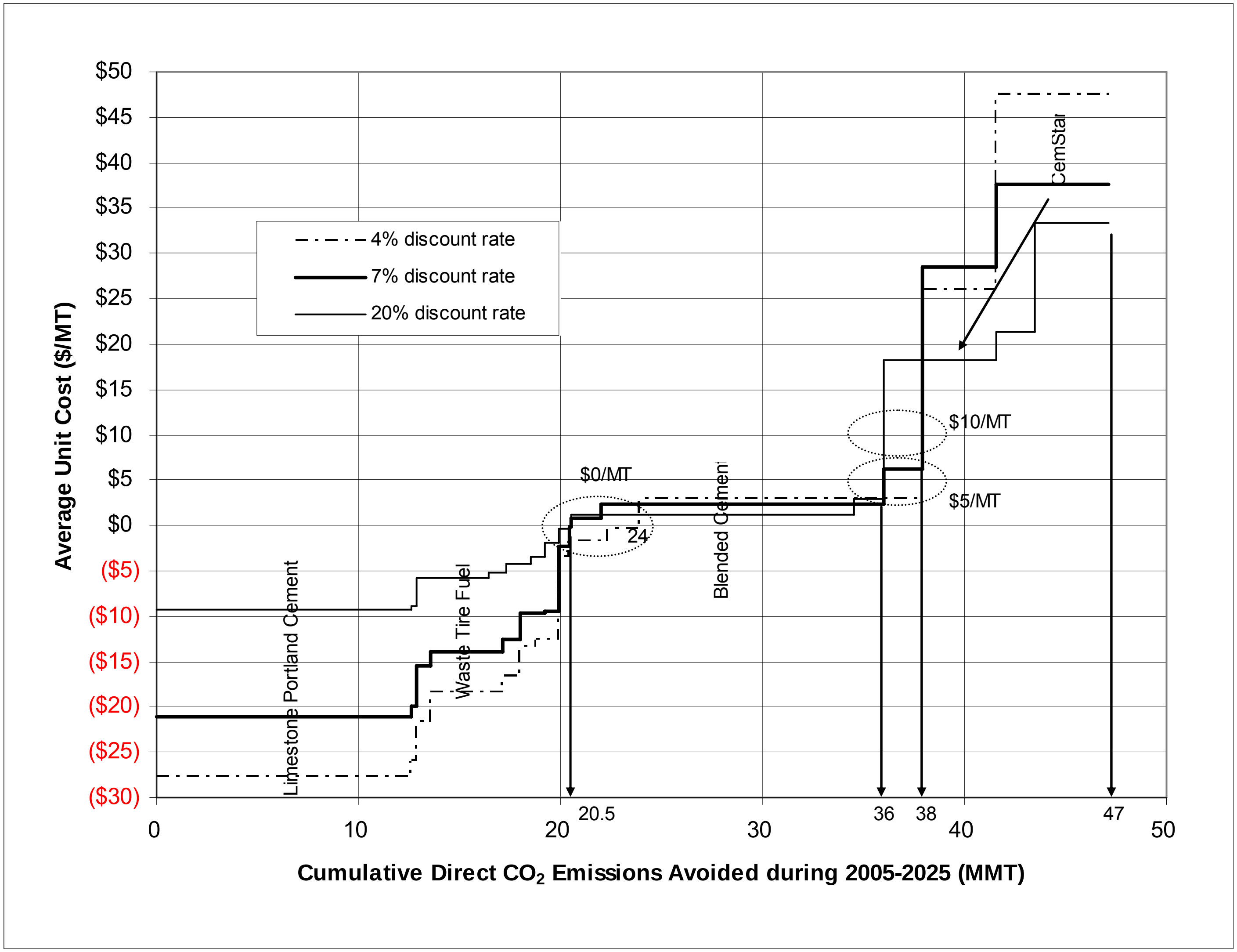

Figure 3: Abatement-Cost Curve for Cumulative Direct CO_2 Emissions from California's Cement Sector during 2005–2025